GSFC CONTAMINATION MONITORS FOR SPACE STATION

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ABSTRACT. This paper describes the Work Package 3 activities in the area of neutral contamination monitoring for the Space Station. Goddard Space Flight Center's responsibilities include the development of the Attached Payload Accommodations Equipment (APAE), the Polar Orbiting Platform (POP), and the Flight Telerobotic Servicer (FTS). GSFC will also develop the Customer Servicing Facility (CSF) in Phase II of the Space Station.

INTRODUCTION

The Work Package 3 Contamination Monitoring System (CMS) includes monitors for the APAE, the POP, and the CSF. Information has been gathered on contamination requirements and sensitivities of candidate payloads. Typical spacecraft have been modeled to evaluate the effects of the Space Station environment on payload performance, and to support the definition of the CMS conceptual design. Based upon these activities, several contamination monitoring candidates have been identified. Furthermore, we have established tentative monitoring locations for science payloads on the Phase I Space Station.

REQUIREMENTS

The RFP for Work Package 3 states several requirements for the sensitivities of the contamination monitors. For total pressure, the requirement is to measure in the range of 2×10^{-10} to 2×10^{-3} Torr. Ionization gauges of the Bayard-Alpert design were tentatively selected to monitor this quantity. For molecular deposition on sensitive surfaces, the required sensitivity is 4.4×10^{-9} g/cm^2/Hz. Quartz crystal microbalances (QCMs) will serve as real-time monitors of molecular deposition. Deposition of particulates must be monitored with a sensitivity of 3.5×10^{-9} g/cm^2/Hz. A "sticky QCM" with an oil coating on the sensing crystal has been proposed for this measurement. For molecular species in the field of view, monitors must be sensitive to partial pressures of 8×10^{-11} to 8×10^{-4} Torr for individual species from 1 to 150 amu. Mass spectrometers were selected to monitor column densities. Remote sensing of particles in the field of view is a technology currently under development. For example, the goal of current Goddard SBIRs is to produce remote particle detectors.

CMS DESIGN DRIVERS

1. USES

There are two primary uses planned for the Work Package 3 contamination monitoring system and the data it collects. One is to verify that the Space Station external environment meets the contamination requirements, as expressed in JSC 30426, the "Space Station External Contamination Requirements Document." Second, as specified in the RFP, the CMS is to act as a warning system for attached science payloads, alerting for appropriate action in the event of high contamination levels.

The CMS may have other secondary roles currently not included in the CMS design: 1) to correlate payload throughput with measured contamination levels; 2) to use the CMS to gather environmental data and compile a data base; and 3) to verify existing computer contamination models.

2. SPACE STATION EXTERNAL CONTAMINATION REQUIREMENTS

The requirements for external contamination levels are stated in JSC 30426, and are summarized in Table 1. A number of suggested changes to the requirements are currently being reviewed by the appropriate working groups.

Table 1. Space Station External Contamination Requirements

Molecular Column Density (molecules/cm^2)	IR emitting: 10^{11}/species, total 3 10^{11} all others: 10^{13}/species, total 5 10^{13}
Molecular Deposition ($g/cm^2 sec$)	300 K, 2 sr FOV: 10^{-16} 300 K, 0.1 sr FOV: 10^{-14} 5 K, 0.1 sr FOV: 2 10^{-13}
Particulates in FOV	> 5 micron diam: 1 particle/orbit/10^{-5}sr < 5 micron diam: TBD
Particulate deposition	TBD

Table 3. Space Station Material Outgassing Rates

Element	Potential Problem	Contam. rate ($g/cm^2 sec$)
Truss	Water outgassing:	
	Uncoated graphite/epoxy	10^{-9}
	Gr/ep + vapor-dep. coating	10^{-12}
	Gr/ep + Al foil coating	none
Solar arrays	Outgassing:	
	95°C	10^{-9}
	30°C	$7 \cdot 10^{-12}$
Thermal blankets	Water outgassing:	
	Initial rate @ 25°C	10^{-9}
	25°C, after 100 hours	10^{-13}
Heat pipes	Ammonia leakage/diffusion	10^{-9} to 10^{-8}
Manned modules	Venting	$6 \cdot 10^{-4}$ g/sec
Attitude control thrusters (O_2/H_2)	Effluent:	
	Forward flow	10^{-5}
	Backflow	10^{-9}
	Residual cloud	10^{-10}
Shuttle PRCS thrusters ($MMH-N_2O_4$)	Forward flow effluent	10^{-5} to 10^{-4}

Table 4. Contamination Monitors Studied

Instrument	Manufacturer or source of data	Range	Sensitivity
Quadrupole mass spec	Air Force Geophysics Lab	1-150 amu	30-50 (M/ΔM)
Mattauch-Herzog mass spec	K. Mauersberger, U. of Minnesota	50 masses meas. simultaneously	200 (M/ΔM)
Bayard-Alpert ionization gauge	Leybold-Heraeus	10^{-10} to 10^{-2} torr	1 %
TQCM	QCM research	10^{-5} g/cm^2	$1.6 \cdot 10^{-9}$ g/cm^{2}Hz
Oil-coated QCM	Faraday labs	10^{-5} g/cm^2	$1.6 \cdot 10^{-9}$ g/cm^{2}Hz
FOV partic. monitor	Miranda labs	1 meter sensing region	1 particle > 5 micron diam.

3. USER REQUIREMENTS

The monitoring system sensitivity must be compatible with the set of user requirements. Table 2 is a compilation of the most current user requirements for Attached Payloads.

Table 2. Space Station Attached Payload User Requirements

Payload	Contamination Sensitivities
Heavy Nuclei Collector	none
Diffuse X-ray Spectrometer	H_2O, deposition < 3 g/cm^2 on crystal panels
Cosmic Dust Collection Facility	all particulates, micrometeoroids, debris
Tropical Regions Imaging Spect.	dep. on optics, H_2O & CO_2 in FOV
Tropical Rainfall Mapping Miss.	unknown
Earth Radiation Budget Expt.	H_2O in FOV
Solar-Terrestrial Observatory	molec. dep, molec. FOV, partic. FOV, warning
LAMAR	partic. in FOV
Cosmic Ray Nuclei Experiment	none
Search & Rescue Interferometer	unknown
Astromag	none
X-ray telescope	dep. cause <10% change in optical properties
X-ray polarimeter	unknown
Active Galactic Nuclei	molec dep <10 Å, col. den. <10^{13} molec/cm^2
All sky monitor	none
Burst & transient monitor	UV-active molec dep & FOV, partic dep & FOV
High energy background expt.	avoid sun, can't observe into RAM
Astrometric telescope	dep <100 Å/yr, col. den. <10^{13}, need warning

4. EXPECTED ENVIRONMENT

Table 3 summarizes outgassing rates for various Space Station materials. This type of information can be used as input for the computer models to assess the Space Station external environment and its effects on both the payloads and the Space Station itself. The CMS design process also benefits from these activities. The identification and characterization of sources is a critical activity, which must and will continue through all the phases of the system design.

5. TECHNOLOGY READINESS

Another major influence on the design of the CMS is the availability of the selected monitors for space flight. Table 4

shows some of the instruments that have been considered. Of these, the quadrupole mass spectrometer and the TQCM have been previously flown. Other Mattauch-Herzog mass spectrometers have also been flown. The Miranda Laboratories remote particle sensor is a Phase II SBIR.

RELATED ACTIVITIES

There are several ongoing activities at the GSFC which are expected to provide new monitoring hardware and environmental information for the Space Station. The Miranda Laboratories remote particle sensor, as mentioned, is in Phase II of its development. It is a laser light-scattering device. SKW, another scientific research company, is developing another remote particle sensor, using a strobe light and an image analyzer. These activities will hopefully bring needed capabilities into what is currently a technologically weak area in space contamination monitoring.

Another SBIR contract from Goddard is with Science and Engineering Associates, Inc. Its objectives are: 1) to develop a flight experiment to measure the gaseous environment of the Space Shuttle; 2) to measure the return flux of a known gas released into the orbiter environment; and 3) to verify a new computer code for molecular transfer. The development of the flight experiment is expected to produce a mass spectrometer well suited to Space Station contamination monitoring. Furthermore, there is a joint NASA/ESA effort to produce an in-flight contamination experiment. The hardware in this case will be QCMs and effusion cells placed on a variable-length mast deployed from the Shuttle bay. The goal is to measure return flux from known sources, and direct flux from the Shuttle payload bay.

SUMMARY

Work Package 3 is developing a contamination monitoring system whose primary goals are to monitor external contamination levels and to act as a warning system for externally mounted science payloads. We have identified several hardware candidates to compose self-contained monitoring packages. Tentative locations on the APAE and POP have been established for these packages. A number of related analytical and laboratory activities are also being performed to support the CMS design.